5.0. STORES MANAGEMENT SET TESTING

5.1. Introduction to Stores Management Set Theory

5.1.1. General

The introduction of increasingly complex air-to-air and air-to-ground weapons requires modern combat aircraft to provide a vast array of varying signal sets to enable effective employment of these weapons. This function is normally performed by a Stores Management Set (SMS) or a Fire Control Set (FCS). For simplicity, the term SMS will be used to describe all systems providing these functions. An SMS can be defined as a system which provides the necessary physical and electrical interfaces for control, normal firing and/or release and jettison of airborne stores and weapons. The SMS is a system peculiar to military aircraft as the vast majority of non-military aircraft have no capability (or requirement) to accommodate releasable stores. Although the bulk of the SMS testing must be completed during the Validation and Verification (V & V) of software, much of the work must be accomplished after installation into the intended platform. This is due to the fact that the majority of the software V & V is performed using simulations of the various aircraft subsystems, none of which will completely simulate the actual hardware once installed. Since this book specifically excludes a discussion of software testing, the remainder of this section is devoted to a treatise of the techniques for performing tests of the fully integrated SMS. Note also that this document will not discuss the test techniques associated with stores separation, aerodynamic effects, static and dynamic structures or targeting accuracy.

5.1.2. Stores Management Set Architecture

Although all combat aircraft contain some form of SMS, these systems accomplish the necessary functions in varying manners. In most modern aircraft, the SMS is a fully digital, software-driven system designed to not only provide the aforementioned functions of weapons control, but also to provide store status, inventory and configuration to the aircraft mission computer. The SMS is generally the only aircraft subsystem which is electrically linked to the onboard stores. Any other subsystem resident in the airplane must communicate to onboard stores through the SMS. With newer aircraft, incorporating data busses to transmit information throughout the avionics suite, this is a logical approach to the architecture, since it ensures that any safeguards designed to avoid inadvertent release or jettison cannot be overridden by another system.

In older aircraft, or those which require less robust systems, the SMS is often a simple system of switches and wires to provide release signals to fire a gun or operate bomb racks. The capabilities and architecture of the SMS are driven by the types of stores to be accommodated and the mission of the aircraft. The test techniques to be discussed are applicable to all SMSs, regardless of the configuration or requirements of the system.

Although each SMS will embody an architecture unique to its host aircraft, most systems will have a minimum of four basic components: (1) controls and displays, (2) a Stores Management Processor (SMP), (3) station decoders, and (4) stores or bomb racks. As the controls and displays are unique in both configuration and function, depending upon the host aircraft, they will be discussed in depth later. Noticeably absent from the list of SMS components are the power supplies for each component. It should suffice to mention that all electrical devices and processors require some sort of energy to function and SMS components are not unique in this manner.

The SMP is the heart of the SMS and receives information from the aircrew via a mission computer, armament control panel, or switch position, as to the desired store type or station to be controlled or released, the release quantity and interval, and/or the mode of the store. In aircraft which incorporate a data bus architecture, the SMP is generally the sole component of the SMS to communicate on the avionics bus. Accordingly, it serves as the only means of passing information from the aircraft to the stores loaded onboard. The SMP controls the release of stores by sending coded signals to each station in the proper sequence and at the proper interval for the desired release. These signals are coded in either the time and/or frequency domain and serve as an added safety measure to effectively eliminate the ability of a simple short or electromagnetic incompatibility to cause inadvertent release of a store. The SMP also ensures that the proper signal set is sent to each weapons station in accordance with the store loaded on that station. These signals could range from a query to determine the level of fuel in an external tank to the two way communication necessary to prepare, fire and guide a fiber optic link missile.

The decoders are switches which provide the necessary voltage to the Cartridge Actuated Devices (CADs) in each bomb rack to release the loaded store. There are two decoder architectures that are used or accommodate this function. In one method, each decoder is connected to the SMP by a separate wire or wire bundle. Although this method is very simple, it requires the use of several signal paths and many wires to achieve the desired level of redundancy to ensure store release upon command. The second method is to place each of the decoders on a data bus and communicate with them using address labeled codes. Upon receiving the proper code, the decoder energizes the CADs, which in turn results in store release. Because of the amount of energy required to fire the CADs in a timely fashion, the decoder will normally draw the required current from a high energy electrical bus. In some aircraft all control commands are also sent to the loaded store via the decoder. In these cases, however, the decoder serves only as a conduit for the signal and does not normally perform any switching functions.

The bomb racks provide the structural interface between the aircraft and the loaded store. These devices are generally designed with one or more hooks which attach to the lugs of the loaded store. The racks also have one or more ejector feet designed to push the store away from the airplane at release. Most racks are gas operated, in that the CADs, once fired, provide high pressure gas which is used to open the hooks and provide energy to extend the ejector feet, thus releasing the store. Most racks also incorporate safety features, such as locking mechanisms, which physically prohibit store release regardless of whether the CADs fire or not, and auxiliary CADs which are designed to open the hooks (but not operate the ejector feet) in the event that the normal release method fails to function. The auxiliary mode is normally designed for emergency situations.

Other features which may be found on bomb racks are positive arm latches, bail bars, arming solenoids and electrical arming receptacles. Positive Arm Latches (PALs) and bail bars are designed to provide secure hook-up points for arming wires and umbilical retaining lanyards. Although the PAL will normally only perform the former function, it is not uncommon for a bail bar to perform either function. Arming solenoids are designed to hold or release arming wires to provide the capability for armed or safe release of weapons, respectively. The electrical arming receptacle is designed to provide weapons incorporating electrical fuzes, normally general purpose bombs, with an electric pulse at release to establish the mode in which the fuse will operate. Figure 23 depicts a block diagram of a generic SMS.

5.1.3. Controls and Displays

The controls and displays of the SMS are designed considering the number of aircrew operating the platform and the required interfaces for the types of stores to be employed. In general, control and display requirements are divided into the following categories: SMS BIT, store inventory and status, store selection, weapons solution display, store control, safe and arm, and release/fire consent. The first four functions are requirements accomplished through the use of multifunction or heads-up displays and keyboards in most modern aircraft. The last three functions are usually performed through the use of cockpit or aircrew accessible switches, with at least one of them being guarded to provide an extra measure of safety.

BIT is normally automatic with provisions for manual initiation. Because a failure of the SMS can lead to potentially catastrophic consequences, it is paramount that this function be extremely reliable. Not only should the BIT check the integrity of the SMS itself, but also the health of the stores loaded onboard the airplane. The BIT should ascertain to what degree the system loaded stores are usable, and clearly communicate this information to the aircrew.

Store inventory may be accomplished in one of two methods: (1) the aircrew or

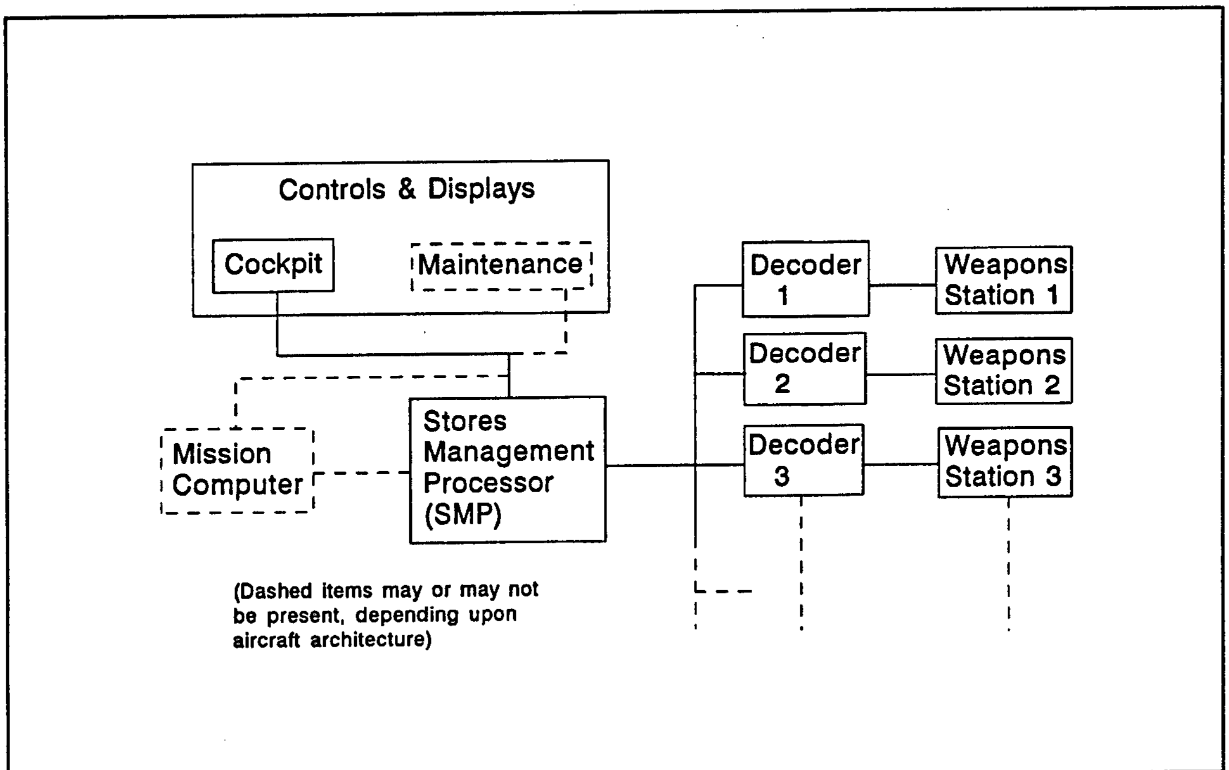

Figure 23: Generic Stores Management Set Block Diagram

maintenance personnel may "tell" the SMS what store is loaded, or (2) the SMS will query the store to identify itself. The former method is generally necessary for weapons that are unable to communicate with the SMS, such as general purpose bombs, cluster munitions and other so called "dumb" weapons. Smart weapons used to communicate with the airplane, such as guided missiles, may employ the latter. Because it is often impossible or impractical for the SMS to determine the initial store inventory, this data is often input by maintenance personnel or the aircrew themselves via an inventory panel or display. Store status includes any report which describes the readiness of the store to be delivered or jettisoned, or whether a malfunction has occurred that will prevent the delivery of the store. For example, if a normal release of a missile is attempted and not achieved, the SMS should inform the aircrew that the missile is hung, or that a required interlock has not been met. Accordingly, if the aircrew has selected a weapon and that weapon requires a finite amount of warm-up or preparatory time, this should also be communicated to the aircrew.

Store selection is the designation of a store to be released, fired or jettisoned. If a weapon is to be employed, this is normally done through selection of a weapon type on most airplanes. For jettison, and on many older airplanes for employment, selection of the station on which the store resides is the method used. On some aircraft, a single purpose Armament Control Panel (ACP) is used to select stores for employment and/or jettison. The method used for store selection should be commensurate with the criticality of employment. For example, air-to-air weapons are often employed in a reactionary manner. Consequently, selection of air-to-air weapons should be extremely convenient. This is why most airplanes possessing an air-to air capability use the Hands-On-Throttle-And-Stick (HOTAS) philosophy, where the pilot need never remove his hands from the throttle or stick to employ an air-to-air weapon. By contrast, air-to-surface weapons are mostly employed in a planned and methodical way, allowing the aircrew sufficient time to use an ACP or an SMS page on a multi-function display.

The weapons solution display, although normally provided to the aircrew via the airplane's Mission Computer (MC), is also SMS related for it is the SMS which informs the MC as to the weapon selected. In the case of unguided munitions, such as air-to-air guns or general purpose bombs, the weapons solution normally would be a HUD cue of where the weapon(s) will impact. For many smart weapons, the SMS provides the interface that tells the aircrew whether the target has been acquired by the weapon. This display can be as simple as a marker on the HUD to inform the pilot of the direction in which the seeker head of the weapon is looking. Weapons with imaging seekers require a cockpit display of the seeker head's image to be presented to the aircrew.

Store control provides pointing commands for weapons seeker heads or podded sensor systems and is usually accomplished through a joystick or other tactile device. It might also involve a determination of the mode in which a store is released. If, for example, an air-to-air missile can be launched in two different modes, say autonomous or command guided, the SMS must provide the means to establish in which mode the missile will be released.

Safe and arm is usually accomplished through a separate switch and provides an added safety measure to prevent accidental release or firing of a weapon. This switch is normally guarded and positioned in such a way as to preclude accidental selection of the ARMED position.

Release/fire consent is usually accomplished through a button or trigger depressed by the aircrew to commit the desired weapon to the intended target. In keeping with the HOTAS philosophy, the pilot normally employs weapons with stick-mounted controls. Jettison, however, is almost always accomplished via an instrument panel mounted switch.

5.1.4. Missions

The mission of the aircraft necessarily defines the requirements of the SMS. For example, an all-weather, two seat strike fighter capable of delivering a wide range of air-to-air and air-to-ground ordnance would require a vastly different SMS than an Anti-Submarine Warfare (ASW) aircraft carrying 10 aircrew designed to deliver torpedoes and general purpose bombs from a bomb bay.

To illustrate the differences in requirements, consider the two counter-examples contrasted above. Although the physical interface between the aircraft and store, normally consisting of a rack and some sort of electrical cabling, may or may not remain the same; each store requires a specific electrical signal set for proper operation. Consequently, the SMS must be designed to provide the necessary electrical interface to "speak" with each of the stores. In the strike fighter and ASW example, the strike fighter might be required to provide signals to perform BIT on all "smart" stores, monitor fuel remaining in external tanks, accept video information from different weapons and provide electrical power for weapon operation, to name a few. The ASW aircraft may not have a requirement to perform any of these functions, but instead it might have to input initial target information to the torpedoes, such as search depth or target signature, provide safety interlocks to prevent weapons release with the bomb bay doors closed and other functions foreign to the strike fighter.

Another key element relevant to the mission, which affects the design of the SMS, is the crew size. The strike fighter is designed to perform its mission in an environment which would quickly overload the crew if the SMS were not highly automated. The modern threat environment requires the strike fighter to perform a high speed, low altitude interdiction mission with the pilot assuming duties of terrain masking/avoidance and air-to-air radar sanitization. Concurrently, the operator is assessing the electronic order of battle and surface to air threats, as well as performing target acquisition and rudimentary navigation. The SMS in this airplane must provide weapons selection with the touch of a single button, with near instantaneous feedback. The operator typically moves a cursor to overlay a cross hair on the sensor display onto the intended target, and within seconds the store is released and the airplane egresses from the target area.

Conversely, the multiplace ASW aircraft operates for extended periods of time in regions far from any counter-air threat. The entire focus of the crew is on the prosecution of the submarine, with only cursory monitoring of navigation and fuel onboard. Consequently, the SMS in the ASW airplane might be designed to require inputs from several of the aircrew to deliver a weapon. One crewmember opens the bomb bay doors. Another insures that the proper target data has been provided to the torpedo. Yet another insures that all interlocks are met before releasing the weapon. The SMS in each airplane requires a totally different level of integration and automation and must be evaluated accordingly.

5.2. Stores Management Set Test Techniques

5.2.1. Stores Management Set Integration Ground Tests

5.2.1.1. Purpose

The purpose of this test is to measure the SMS firing pulse, release interval and physical interface compatibility with the host aircraft and to assess the effects that these parameters have upon the utility of the SMS.

5.2.1.2. General

The evaluator must ensure that the SMS will provide the proper signals to each store in accordance with the requirements of the store and the desires of the aircrew. These tests provide the required data to verify that these requirements and desires are met.

5.2.1.3. Instrumentation

Test kits/weapons simulators and electrical test equipment are required. The specific equipment is chosen to suit the SMS under test and the particular stores to be carried by the airplane.

5.2.1.4. Data Required

Record the fire pulse voltage, and current and duration for each discrete signal to be provided to the station for release and motor fire. Record the time difference between the arrival of the firing pulse at each station and the cockpit initiation of release. Document comments concerning the fit of the electrical interfaces with the test equipment couplers.

5.2.1.5. Procedure

Connect the weapon test kit and the electrical test equipment to the station(s) to be tested. Ensure that all stations to be tested report a store aboard (normally, hooks closed will accomplish this). Provide the SMS with an inventory corresponding to the test kits attached to each station. Input a desired interval between releases. Select the weapons or stations to be activated and command release of those stations. Repeat for all likely station and store combinations.

5.2.1.6. Data Analysis

The voltage, current and duration of each firing pulse must be sufficient to perform the intended function, i.e., release pulses should be able to fire CADs in the bomb racks, electrical fuzing pulses should be of the correct voltage and polarity and motor fire pulses should be of sufficient energy to start the intended rocket motor. Fire pulses should be sufficient and consistent regardless of the number of stations selected. Intervals between release pulses should be in accordance with that selected in the cockpit. Release pulses should arrive ONLY at those stations selected and in the correct order in accordance with an established protocol or an order which was available for selection in the cockpit. The time from the release command to the arrival of the fire pulse at the selected station(s) should be commensurate with the mission and intended stores to be employed. All couplers should fit snugly and without undue effort. Umbilicals should mate properly when using inert stores. Relate improper weapons commands to the likelihood of a hang-fire, inadvertently activating the wrong store, or a missed target as appropriate. Relate poor coupler and umbilical fits to the possibility of damaging the connector racks or stores.

5.2.1.7. Data Cards

A sample data card is presented as card 68.